Optimizing Voltage/ Temperature/ Frequency Margin Testing

Michael A. Gross
Jet Propulsion Laboratory

Overview

- Voltage Temperature Frequency Margin Testing (VTFMT) is a testing practice of exceeding the expected flight limits of voltage, temperature, and frequency to obtain the sensitivity characteristics and functional performance of the designed electronic elements.
- VTFMT is a viable alternative for circuits that are difficult or impossible to simulate or analyze, and for flight projects where tradeoff of risk versus development time and cost are necessary.
- Taguchi Design of Experiments (DOE) incorporated to shrink number of test runs.
- VTFMT/Taguchi combination shows promise as screening test for multiple build hardware.
    - ☞ Advantages:
        - Utilizes brass board, engineering models and other production units
        - Allows Tailoring of tests to hardware
        - Reduces schedule and resource requirements
        - Better quantification /understanding of performance

Current Testing Practices at JPL

- Typically testing includes either a full factorial experiment (all combinations of variables) of performance or some hybrid thereof (extremes, random, etc.).
- VTFM Testing is a purely qualitative approach allowing full characterization over the expected environments.
  - Full characterization is a cost and time driver for multiple build hardware.
- A more systematic approach to quantifying performance can be tried.
  - Typically a pass/fail criteria is instituted and the units are accepted based on this criteria.
  - To quantify the pass or fail of an Instrument/ Engineering Unit it is possible to design an experiment combining testing and analysis where the results are mapped in performance contours.
- For this reason the Taguchi/VTFMT combination is being developed.

Taguchi Method

- Limits the number of experiments necessary to optimize a process or a product.
- Discovered it can be turned around and used to de-optimize
- Studies interactions and individual effects of parameters by orthogonality.
- Orthogonal matrix established by:
  - ☞ Number of parameters and levels
  - ☞ Interactions
  - ☞ Degrees of Freedom
  - ☞ Quality factor (overall measure of performance) of interest.

Voltage/Temperature/Frequency Margin Testing

- VTFMT is often used in Lieu of Worst Case Analysis (WCA), but its use does not preclude all analyses, in particular the need for a Part Stress Analysis (PSA).
- The required input and output characteristics of the unit/board under test and characteristics of assemblies interfacing to the unit/board under test are as follow: 1)Input Stimulus, 2) .Input and Load Impedance, 3) Frequency Limitations, 4) Timing Constraints, 5) Minimum and Maximum Operating Voltages , 6) Power Constraints
- Produces a qualitative "feeling" of how robust a design is.
- Margin/Robustness is estimated by varying the parameters of:
    - ☞ Bias Voltage
    - ☞ Temperature
    - ☞ Input signal or clocking frequencies
- Shows whether unit is in spec over the defined VTF environment which is defined by the use environment plus margin.

Hardware Provisions For Performing Voltage/Temperature/Frequency Margin Testing

- Test monitoring points must be implemented into the initial design at a level where unit functionality and performance can be monitored.
- Test injection points must also be implemented to allow access to secondary voltages and internal timing.
- These test/injection points must be considered in the design phase before hardware is built.
- An ideal VTFMT applies power downstream of voltage regulation devices to permit an adequate range of voltage variations.
- Voltage, Temperature and Frequency must extend beyond the nominal environment.and must remain within manufacture device limitations.
- It is imperative to perform a Parts Stress Analysis (PSA) in order to ensure that the manufacturer's ratings are not exceeded.

Application: Microwave Limb Sounder Project

- Multiple build filter banks
  - 4 Brassboard
  - 2 Engineering Models(EM)
  - 21 Flight Models (FM)
- Original test regime included:
  - First Brassboard : +/-4.75,5.0 &+/-5.25 @ 25 C (Ambient)
  - First and last Brassboard : +/-4.75,5.0 &+/-5.25 @ -10 and 55 C (Ambient).
  - One (1) EMs : +/-4.75,5.0 &+/-5.25 @ 55,45,0 and -10 C (Ambient)
  - Four (4) FMs (random) : +/-4.75,5.0 &+/-5.25 @ 55,45,0 and -10 C (Ambient)
  - 17 Remaining FMs : +/-4.75,5.0 &+/-5.25 @ 55 and -10 (Ambient)
- Each tests is judged by a cut and dry pass or fail.
- Total Tests: 171

Application: Microwave Limb Sounder Project (Cont'd)

- VTFMT/Taguchi testing:
  - Quality Factor defined as the combination of :
    - ☞ Filter Gain
    - ☞ Linearity
    - ☞ Frequency Response
    - ☞ Channel Offset
  - One (1) Brassboard (previously accepted as good): Full Factorial experiment (+/-4.75, +/-5, and +/-5.25 @ 70,60,50,40,30,20,10,0,and -10 C)
    - ☞ Produce performance contours.
  - One (1) EM and one (1) Brassboard : Taguchi Experiment (+/-4.75, +/-5, and +/-5.25 @ 70, 40, 10 and -10 C)
    - ☞ Analyze parameter effects on performance.
    - ☞ Determine existence and estimate interactions between parameters.
    - ☞ Compare performance against performance contours.
    - ☞ Estimate Optimized and De-optimized V/T parameter sets and performance
      - ↙ Rerun tests at these levels and compare predictions.
  - Test FMs at optimized and de-optimized level
    - ☞ Compare results to expected performance
- Total Tests: 97

Pros of Combined VTFMT/Taguchi Method

- Decreases number of tests
  - ☞ Schedule and resource reduction
  - ☞ 171 tests decreased to 97
- Produces performance maps
- Assures that best and worst operating conditions are bounded
  - ☞ Extreme values don't always define the boundaries of operation
- Removes guessing game in test design
  - ☞ Allows continual refinement of DOE
  - ☞ Systematic means of studying "environmental" impacts on performance
    - Parametric interactions.
    - Qualitative and quantitative estimation of performance